Deep water TLP Tether System

This invention relates to the art of offshore structur s and, more particularly, to tension leg platforms (TLP) for exploitation of deep sea hydrocarbon reserves .

5   Mooring elements, or tethers on tension leg platforms are anchored to the sea-bed. They usually consist of steel pipes and are kept in tension by the buoyancy of the platform.

With the gradual depletion of onshore and shallow subsea subterranean hydro-

10   carbon reservoirs, the search for additional petroleum reserves is being extended into deeper and deeper waters. As such deeper reservoirs are discovered, incre-asingly complex and sophisticated production systems are being developed. It is projected that soon, offshore exploration and production facilities will be required for probing depths of 1500m or more.

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One way of reaching these depths is by using Tension Leg Patforms. A TLP comprises a semi-submersible-type floating platform anchored to foundations on the sea bed through members or mooring lines called tension legs or tethers. The tension legs are maintained in tension at all times by ensuring that the buoy-

20   ancy of the TLP exceeds its operating weight under all environmental conditions. The TLP is compliantly restrained by this mooring system against lateral offset allowing limited surge, sway and yaw. Motions in the vertical direction of heave, pitch and roll are stiffly restrained by the tension legs.

25   External flotation systems can be attached to the legs but their long-term reliabi-lity is questionable. Furthermore, added buoyancy of this type causes an in-crease in the hydrodynamic forces on the leg structure.

TLPs' based on today's technology are considered competitive down to 1,000-

30   1,500m. Beyond this depth, the tether system becomes increasingly heavy, re-quiring an increased platform size to carry the tether weight. This results in a lar-ger platform, which has a significant impact on the overall cost.

For a TLP at 3,000m, a conventional tether system (one thickness, one diameter) represent a weight almost equal the payl ad. In previous designs, it has been proposed to reduce the wall thickness at the top to reduce the weight penalty.

A solution to avoid these disadvantages related to the TLP, is to modify the tether system to reduce the need for increased hull size. The industry has devoted a considerable effort to develop tether systems based on various designs. Filling tether pipes with low density material, pressurising the interior to increase the hydrostatic capacity and replacing the steel tether pipes by composites are examples of these efforts.

Another solution can be found in NO 1997 3044, showing a design used for depths down to 700 m, built by pipe sections with a diameter between 0,5 to 1,2 m. The overall buoyancy of the tension leg is meant to be more or less neutral. This is achieved by adding an additional floating body at the top of the pipe.

NO 1997 3045 shows a welding connection on a tension leg. The publication shows two pipes of different diameter and wall thickness' welded together.

The object of the present invention is to overcome the above mentioned deficiencies and to design tethers for TLP's that reduces the necessary added payload on the platform due to the tether weight. This object is achieved by a TLP as defined in the appending claims.

The invention relates to a tether system for TLP's, with tethers having upper and lower pipe sections, the tethers having a reduction of the diameter towards the seabed.

The invention is a concept for modifying today's technology for use in ultra deep waters. By introducing reductions in the tether diameter, the lower sections of the tether towards the sea bed will normally be negatively buoyant because of the considerable wall thickness necessary to withstand the hydrostatic pressure. The upper sections can mor easily be made bu yant as the hydrostatic pressure is

less at the top. This will help to balance the overall weight of the upper and lower sections.

The tether pipes are dimensioned to carry the tension from a platform consisting of a nominal pre-tension plus the tension variation by functional and environmental loads. The pipes are kept empty, to reduce the weight/increase buoyancy. The pipes must not only be designed to withstand the loads applied by the platform, but also has to resist the hydrostatic pressure from the surrounding sea. This becomes more prominent as the depth/hydrostatic pressure increases. At great depths (in the order of 1,000m) the pipes can no longer be designed to have a neutral buoyancy (a diameter to thickness ratio of about 30). In order to withstand the pressure, the diameter to thickness ratio has to be reduced, which results in added load on the platform.

The thickness of each section is sized according to capacity. It should also be considered that the tether vertical stiffness is critical for performance, and it is therefore favourable to maintain a fairly equal stiffness/length of each section.

The reduction of overall diameter will typically be made in steps, with intersections between the steps. The number of steps will depend on the length of the tether/depth of which it is to be used etc.
In-between each diameter, a transition piece carries the load. This is a well proven detail from previous TLP applications.

The tethers may have a gradual transition between the upper and lower sections instead of the above described steps, but such tethers are less likely to be used as such tethers probably will require a more complex manufacturing process.

With near neutral tethers, the reduction of the hull weight is in the order of 30 percent as compared the hull weight when tethers according to prior art are used. This is du to the decrease of added payload when tethers of the invention are used.

Th invention will now be explained in more detail, with reference to the drawings in which

Figure 1 shows a tension leg platform with tethers according to the present in-
5   vention;
Figure A1 shows the tension distribution of the two concepts;
Figure 2 shows a tether string according to the invention;
Figure 3 shows a cross section of a diameter transition section; and
Figure 4 shows an optimisation chart where a tethers outer diameter and the wall
10   thickness are plotted to show how buoyancy, stiffness and hydrostatic capacity
varies.

The following gives an embodiment by way of the following non-limiting example.

15   A TLP (4) with one step and two tethers (6) having two diameters holding the
platform is shown on Fig 1. A transition piece (3) between the diameters is shown
on Fig 3 in detail. An upper part of a tether (1) may then have a diameter of
142 mm and a wall thickness of 24.5 mm, whereas the lower part (2) has an
outer diameter of 76 mm and a wall thickness of 42 mm. The tethers are an-
20   chored to foundations (5).

A tether with two steps is shown on Fig 2.

Samples of further variations in loads, dimensions and configurations are illus-
25   trated in Table 1. The embodiments suggests a wellhead platform in West African
environment. The deck weight includes the facilities, the structural steel and the
operational loads, including the riser tensions. The riser tensions are increased
with water depth. The hull and displacement are increased to carry the deck load
and the tether pretension.

30   The thick tether system represents the conventional one thickness tether, which
has to have a large thickness to diameter ratio, to withstand the hydrostatic pres-
sure at the bottom. The stepped tether system represents the invention, which
allows for reduction of the tether pretension. This allows for reduction of th dis-
35   placement and of the hull weight.

Table 1 — West Africa TLP Application

WATER DEPTH	(m)	1000m	1500m		2000m		3000m		
TETHER SYSTEM	(·)	THICK	THICK	STEPPED	THICK	STEPPED	THICK	STEPPED	MAX. STEP
DECK WEIGHT	(t)	4,800	5,000	5,000	5,300	5,300	5,900	5,900	5,900
RISER TENSION	(t)	2,800	4,200	4,200	5,600	5,600	8,400	8,400	8,400
HULL & BALLAST	(t)	5,300	6,000	5,800	7,100	6,400	10,100	8,200	7,700
TETHER PRETENSION	(t)	2,400	3,300	2,600	5,500	3,000	13,000	6,200	4,500
DISPLACEMENT		15,300	18,500	17,600	23,500	20,300	37,400	28,700	26,500
TETHERS NO. OF DIAMETERS		1	1	2	1	2	1	5	10
DIAMETER (top/bott.)	Inch	26	30	48/24	32	52/28	34	56/30	56/30
DIAMETER (top/bott.)	mm	66	76	117/61	81	132/71	86	142/76	142/76
THICKNESS (top/bott)	mm	22.2	28.5	38.5/23	35.5	34.5/31	47.5	24.5/42	24.5/42
MAX. LOAD – TOP	(kN)	7,200	8,900	8,100	12,400	8,000	24,000	14,700	12,600
WEIGHT in WATER	(t)	0	70	-10	300	20	1,100	300	70

The above described embodiments use steel as the construction material, but the invention is also meant to cover other materials such as composites.

TITLE:

DEEP WATER TLP TETHER SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to the art of offshore structures and, more particularly, to tension leg platforms (TLP) for exploitation of deep sea hydrocarbon reserves.

Mooring elements, or tethers on tension leg platforms are anchored to the seabed. They usually consist of steel pipes and are kept in tension by the buoyancy of the platform.

With the gradual depletion of onshore and shallow sub sea subterranean hydrocarbon reservoirs, the search for additional petroleum reserves is being extended into deeper and deeper waters. As such deeper reservoirs are discovered, increasingly complex and sophisticated production systems are being developed. It is projected that soon, offshore exploration and production facilities will be required for probing depths of 1500m or more.

One way of reaching these depths is by using Tension Leg Patforms. A TLP comprises a semi-submersible-type floating platform anchored to foundations on the sea bed through members or mooring lines called tension legs or tethers. The tension legs are maintained in tension at all times by ensuring that the buoyancy of the TLP exceeds its operating weight under all environmental conditions. The TLP is compliantly restrained by this mooring system against lateral offset allowing limited surge, sway and yaw. Motions in the vertical direction of heave, pitch and roll are stiffly restrained by the tension legs.

External flotation systems can be attached to the legs but their long-term reliability is questionable. Furthermore, added buoyancy of this type causes an increase in th hydrodynamic forces on the leg structure.

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TLPs' based on today's technology are considered competitive down to 1,000-1,500m. Beyond this depth, th tether system becomes increasingly heavy, requiring an increased platform size to carry the tether weight. This r sults in a larger platform, which has a significant impact on the overall cost.

For a TLP at 3,000m, a conventional tether system (one thickness, one diameter) represent a weight almost equal the payload. In previous designs, it has been proposed to reduce the wall thickness at the top to reduce the weight penalty.
A solution to avoid these disadvantages related to the TLP, is to modify the tether system to reduce the need for increased hull size. The industry has devoted a considerable effort to develop tether systems based on various designs. Filling tether pipes with low-density material, pressurising the interior to increase the hydrostatic capacity and replacing the steel tether pipes by composites are examples of these efforts.

Another solution can be found in NO 1997 3044, showing a design used for depths down to 700 m, built by pipe sections with a diameter between 0,5 to 1,2 m. The overall buoyancy of the tension leg is meant to be more or less neutral. This is achieved by adding an additional floating body at the top of the pipe.

NO 1997 3045 shows a welding connection on a tension leg. The publication shows two pipes of different diameter and wall thickness' welded together.

GB 2 081 659 A shows a floating platform mooring system for use in exploiting sub sea oil shoals that consists of a platform structure and an array of vertical tubular anchoring lines connected to the upright of the platform structure and to anchoring blocks on the sea bed. The patent shows anchoring lines consisting of a steel tube having resistance to yield stresses and having upper and lower sections. Th upper section is a st el rod with a fl xural stiffness which decreases from its point of connection to the upright. The lower section of the

anchoring line has a hollow configuration and is fixed to an anchoring block in order to achieve an optimum exploitation of th structural material.

However, the patent does not address the problems relating to the weight and pressure resistance of deep sea tension legs.

SUMMARY OF THE INVENTION

The object of the present invention is to overcome the above-mentioned deficiencies and to design tethers for TLP's that reduces the necessary added payload on the platform due to the tether weight. This object is achieved by a TLP as defined in the appending claims.

The invention relates to a tether system for TLP's, with tethers having upper and lower pipe sections, the tethers having a reduction of the diameter towards the seabed.

The invention is a concept for modifying today's technology for use in ultra deep waters. By introducing reductions in the tether diameter, the lower sections of the tether towards the sea bed will normally be negatively buoyant because of the considerable wall thickness necessary to withstand the hydrostatic pressure. The upper sections can more easily be made buoyant, as the hydrostatic pressure is less at the top. This will help to balance the overall weight of the upper and lower sections.

The tether pipes are dimensioned to carry the tension from a platform consisting of a nominal pre-tension plus the tension variation by functional and environmental loads. The pipes are kept empty, to reduce the weight/increase buoyancy. The pipes must not only be designed to withstand the loads applied by the platform, but also has to resist the hydrostatic pressure from the surrounding sea. This becomes more prominent as the depth/hydrostatic pressure increases. At great depths (in the order of 1,000m) the pipes can no longer be designed to have a neutral buoyancy (a diameter to thickness ratio of about 30). In order to

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withstand the pressure, the diameter to thickness ratio has to be reduced, which results in added load on the platform.

The thickness of each section is sized according to capacity. It should also be considered that the tether vertical stiffness is critical for performance, and it is therefore favourable to maintain a fairly equal stiffness/length of each section.

The reduction of overall diameter will typically be made in steps, with intersections between the steps. The number of steps will depend on the length of the tether/depth of which it is to be used etc.
In-between each diameter, a transition piece carries the load. This is a well-proven detail from previous TLP applications.
The tethers may have a gradual transition between the upper and lower sections instead of the above described steps, but such tethers are less likely to be used as such tethers probably will require a more complex manufacturing process.

With near neutral tethers, the reduction of the hull weight is in the order of 30 percent as compared the hull weight when tethers according to prior art are used. This is due to the decrease of added payload when tethers of the invention are used.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be explained in more detail, with reference to the drawings in which

Figure 1 shows a tension leg platform with tethers according to the present invention;
Figure A1 shows the tension distribution of the two concepts;
Figure 2 shows a tether string according to the invention;
Figure A2 shows a schematic representation of tether pipe utilization.
Figure 3 shows a cross section of a diameter transition section; and

Figure 4 shows an optimisation chart wh r a tethers out r diam ter and the wall thickness are plotted to show how buoyancy, stiffness and hydrostatic capacity varies.

DETAILED DESCRIPTION OF THE INVENTION

The following gives an embodiment by way of the following non-limiting example.

A tension leg platform (4) with one step and two tethers (6) having two diameters holding the platform is shown on Fig 1. A transition piece (3) between the diameters is shown on Fig 3 in detail. An upper part of a tether (1) may then have a diameter of 142 mm and a wall thickness of 24.5 mm, whereas the lower part (2) has an outer diameter of 76 mm and a wall thickness of 42 mm. The tethers are anchored to foundations (5).

A tether with two steps is shown on Fig 2.

The figure shows three tubular sections interconnected with two transition pieces (3). The three tubular sections have a reduction of the diameter towards the sea bed.

Figure A2 is a schematic representation of tether part utilization.

Samples of further variations in loads, dimensions and configurations are illustrated in Table 1. The embodiment suggests a wellhead platform in West African environment. The deck weight includes the facilities, the structural steel and the operational loads, including the riser tensions. The riser tensions are increased with water depth. The hull and displacement are increased to carry the deck load and the tether pretension.

The thick tether system represents the conventional one thickness tether, which has to have a large thickness to diameter ratio, to withstand the hydrostatic pressure at the bottom. The stepped tether system represents the invention, which allows for reduction of the tether pr tension. This allows for reduction of the displacement and of the hull weight.

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Table 1   West Africa TLP Application

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RISER TENSION	(t)	2,800	4,200	4,200	5,600	5,600	8,400	8,400	8,400
HULL & BALLAST	(t)	5,300	6,000	5,800	7,100	6,400	10,100	8,200	7,700
TETHER PRETENSION	(t)	2,400	3,300	2,600	5,500	3,000	13,000	6,200	4,500
DISPLACEMENT		15,300	18,500	17,600	23,500	20,300	37,400	28,700	26,500

TETHERS									
NO. OF DIAMETERS		1	1	2	1	2	1	5	10
DIAMETER (top/bott.)	Inch	26	30	46/24	32	52/28	34	56/30	56/30
DIAMETER (top/bott.)	mm	66	76	117/61	81	132/71	86	142/76	142/76
THICKNESS (top/bott)	mm	22.2	28.5	38.5/23	35.5	34.5/31	47.5	24.5/42	24.5/42
MAX. LOAD – TOP	(kN)	7,200	8,900	8,100	12,400	8,000	24,000	14,700	12,600
WEIGHT in WATER	(t)	0	70	-10	300	20	1,100	300	70

The above described embodiments use steel as the construction material, but the invention is also meant to cover other materials such as composites.